Some peculiarities of hydroecological features of the Seversky Donets River (Rostov region)

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Abstract. Climate change leads to the transformation of the water regime of rivers. This paper examines the changes that occur with the Seversky Donets River in the Rostov region. To assess the influence of meteorological factors, studies of temperature changes (1974 - 2020) and precipitation (2001 - 2020) were conducted. An increase in the average annual (from 8 °C to 9.7 °C) and winter (-5.3 °C to -3.6 °C), spring (8.6 °C to 9.9 °C), summer (20.6 °C to 23.1 °C) and autumn (8.1 °C to 9.3 °C) were revealed. Precipitation data showed multidirectional processes; 2001-2010 were drier (294 mm) than the average (419 m), and 2011-2020 wetter (436 mm). Water flow changes analyse in the River Seversky Donets from 1982 to 2020. The assessment of the influence of hydrometeorological factors on the transformation of river flow is an important aspect. There is a tendency to decrease the average annual expenditure. The highest and lowest annual flow of the river was recorded in the 2000s. The minimum water flow in the river was recorded in 2020 (33.95 m³/s), and the maximum in 2006 (211.2 m³/s). The territory is experiencing high anthropogenic pressure in an arid climate. Significant seasonal changes are characteristic of the water flow in the River Seversky Donets. The maximum impact on changes in water levels in the river is provided by snow nutrition, which is associated with uneven water consumption throughout the year.

1 Introduction

Prolonged periods of drought and low water led to the transformation of the river regime, a decrease in the runoff, deterioration of the ecological state, and a negative affecting the fishery [1-17]. Changes in the hydrological regime of rivers and the waterlogging of adjacent territories lead to the degradation of natural associations. Therefore, the analysis of climate change in catchment areas is an important task that contributes to the preservation of natural ecosystems. Based on the analysis of daily data from weather stations in the south of the European part of Russia, long-term trends of changes in precipitation amounts and air temperatures (average, absolute minimum, and absolute maximum) for different periods of the year have been established. The purpose of the study is to analyze the influence of climatic factors on the change in the flow of the Don River basin. The study

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and generalization of data on the water regime of the rivers of the Don basin were carried out in the works [15-24].

Arid climate, high population density, and economic activity are the reasons for the aggravation of the situation with high-quality drinking water in some regions. These areas include the Rostov region. The Seversky Donets River is the largest tributary of the Don River. The purpose of the work is to carry out a comprehensive description of the river and establish its hydrological changes in the conditions of climatic and anthropogenic impact.

2 Materials and methods

The source of the Seversky Donets River is located on the slopes of the Kursk plateau at an altitude of 218 km. The length of the river is 1053 km, and the catchment area is 98900 km². The surface of the basin is a slightly undulating plain with a general slope to the southeast. Numerous river valleys and gullies cross the surface. The river valley is asymmetrical. The pool is located in the steppe zone. The floodplain of the river is up to 0.5 km wide, swampy in places. The riverbed is meandering. There are many rapids and rifts on the river. The width of the riverbed varies mainly from 30 to 70 m. The bottom of the riverbed is mostly sandy, with fluctuations in depth. There are many small lakes in the river basin. Reservoirs and ponds have a significant distribution. The river is mainly snow-fed; therefore, the consumption during the year is uneven [19-21].

The study of the level regime began in the 30s. In the annual course of the level, there is a spring flood. The beginning of the flood comes on March 3, the greatest urgent expenditure falls on March 25, the end of the flood on May 20. The average duration of the flood is 79 days on average. On average, the runoff during the flood is 47 %. The summer-autumn boundary is set from June to October; it is usually interrupted by rain floods. In winter is low water period.

The initial data were the data of the Don Basin Water Management of the Federal Agency for Water Resources, the automated information system State Water Register "AIS GVR", reports of the environmental bulletin of the Rostov region [21-22]. The main research methods are geographical-hydrological, statistical, hydrological analogy, visual field surveys. Calculations and graphical constructions are performed in the MS Excel computer program.

The Seversky Donets River is a source of drinking and technical water supply. It is also a receiver of a large amount of recycled water from industrial enterprises, municipal and agricultural enterprises, which negatively affect the quality of water in it [21].

3 Results and Discussion

The climate in the river basin is temperate continental. Summer is hot, and the second half of it is dry. Winter is relatively cold, with sharp east and southeast winds, thaws, and ice. The average summer temperature is +21.8...23.1 °C, average winter temperature is -6...-8 °C. Temperature changes affected both the warm season and the cold season. During the warm period from April to September, there is an increase in air temperature from 17.2 °C (1974 - 1980) to 19 °C (2011-2020). In the cold period, there is a warming from -2.4 °C (1974 - 1980) to 0.7 °C (2011-2020) (table 1). Average temperature values show a steady upward trend. The average annual temperature has changed from 8 °C (1974 - 1980) to 9.7 °C (2011-2020). The warmest years in the series of observations were the years of the current century. Thus, the temperature steadily rose throughout the year, most noticeably in winter. The annual increase in air temperature is associated with a reduction in the duration and warming of the frost-free period.
Precipitation plays a significant role in the hydrological regime, in the process of river flow formation. The average annual precipitation (550 mm) falls in the most elevated part of the Donetsk ridge. Rains often fall in the form of short-term showers. The average annual precipitation is 419 mm (table 2). Unlike temperature, precipitation observations are characterized by fragmentation and a short observation period. Comparative analysis of long-term data and the amount of precipitation received in the last years of the twentieth century. A comparative analysis of long-term data and the amount of precipitation received in the last years of the twentieth century shows the disparity of changes. The average long-term precipitation values are 419 mm. Multidirectional processes characterize the last 20 years, the period 2001 - 2010 was drier than the average long-term values, and 2011 - 2020 is wetter. The fluctuation of the monthly precipitation totals is quite large from 0 mm (August 2007 - September 2020) to 210 mm (May 2010). During the year, the maximum amount of precipitation falls in the warm season. In warm time of the year accounted for 63% of precipitation in a long-term perspective. The period of 2001 - 2010 was very dry summer, when dropped 45% less rain than in a long-term perspective. The hydrological role of precipitation of the warm period is ineffective for the power of rivers, because required for evaporation. In the winter of 2001 - 2010 fell 56 % lower than the average. A non-statistically significant trend is recorded for precipitation, and the assessment of seasonal precipitation redistribution is more important.

Table 1. Average seasonal temperature, Belaya Kalitva.

<table>
<thead>
<tr>
<th>Year</th>
<th>Warm period</th>
<th>Cold period</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>17.9</td>
<td>-1.2</td>
<td>-5.6</td>
<td>8.4</td>
<td>21.9</td>
<td>8.6</td>
</tr>
<tr>
<td>1974-2022</td>
<td>18.0</td>
<td>-0.6</td>
<td>-4.3</td>
<td>8.9</td>
<td>21.9</td>
<td>8.8</td>
</tr>
<tr>
<td>1974-1980</td>
<td>17.2</td>
<td>-2.4</td>
<td>-5.3</td>
<td>8.6</td>
<td>20.6</td>
<td>8.1</td>
</tr>
<tr>
<td>1981-1990</td>
<td>17.5</td>
<td>-1.6</td>
<td>-4.5</td>
<td>8.3</td>
<td>21.3</td>
<td>8.3</td>
</tr>
<tr>
<td>1991-2000</td>
<td>17.6</td>
<td>-1.2</td>
<td>-4.3</td>
<td>8.6</td>
<td>21.7</td>
<td>8.0</td>
</tr>
<tr>
<td>2001-2010</td>
<td>18.4</td>
<td>0.8</td>
<td>-3.9</td>
<td>9.2</td>
<td>22.5</td>
<td>9.7</td>
</tr>
<tr>
<td>2011-2020</td>
<td>19.0</td>
<td>0.7</td>
<td>-3.6</td>
<td>9.9</td>
<td>23.1</td>
<td>9.3</td>
</tr>
</tbody>
</table>

The intra-annual distribution of river runoff is related to the magnitude and seasonal distribution of precipitation, soil and air humidity, evaporation, and other factors. Climatic changes cause increased contrasts in the water content of rivers. A comparative analysis of these changes in river flow shows that spring runoff dominates and is 39%, winter runoff is 26%, autumn runoff is 20% and summer runoff is 15% (figure 1). During the period 2008-2020, there were some transformations of the runoff. There is a tendency to decrease the flow during the period under review in the alignment of the city of Belaya Kalitva. The highest water content in the spring period (49%) occurred in 2010, and the least water content was in 2020 and 2016 (31%). A decrease in the volume of runoff in spring is accompanied by a decrease in the maximum flood. In summer, there is a tendency to increase runoff. With an average value of 15%, the highest runoff in the summer period
occurred in 2020 and 2014 (19%), and the lowest in 2010 and 2013 and amounted to 12%. The autumn runoff is characterized by a tendency to decrease the value of the runoff. The highest water content in the autumn period was in 2013 (25%), and the lowest in 2017 (14%). Winter runoff with an average value of 26%, the maximum runoff in winter was in 2015 (30%), and the minimum in 2008 (21%). The trend line on the charts of seasonal water consumption has a positive slope for summer and winter, and a negative slope for spring and autumn. The redistribution of runoff has both positive and negative consequences. For example, there is a decrease in the number of catastrophic spring floods, but on the other hand, the risk of shallowing decreases. No stable trends in seasonal runoff have been recorded.

**Fig. 1.** Proportion of seasonal runoff in the annual river flow, % (2008 - 2020).

Significant seasonal changes are characteristic of the water flow in the Seversky Donets River. The maximum impact on changes in water levels in the river is provided by snow nutrition, which is associated with uneven water consumption throughout the year. The impact of snow supply belongs to 70-80%, in low-water years this value may decrease to 20-30%. Groundwater plays a significant role. In the annual course of the level, a maximum is observed in the spring period. The intensity of the flood is determined by the water content of spring. The decline in the level ends in the second decade of April - the second decade of May. The summer-autumn snowfall is set in the period from June to October, which can be interrupted by rain floods. The level of winter autumn is higher than summer-autumn. Winter low water is disturbed by the rise of the level during thaws.

The annual course of the water temperature is consistent with the annual air temperature. The changes happen smoothly. The average long-term decadal values of water temperature from January to March are close to 0 °C. In April, there is an intense increase in water temperature to 14-18 °C, from May to June, the intensity of the increase decreases and the water temperature in summer increases to 22-24 °C. In autumn, the reverse gradual
decrease in water temperature occurs. The thermal regime may be disrupted due to an increase in the role of soil nutrition or an increase in economic activity [22].

Because of the calculations, it was revealed that for the period from 1982 to 2020, the minimum water flow in the river was recorded in 2020 (33.95 m$^3$/s), and the maximum in 2006 (211.2 m$^3$/s) (figure 2, 3). The average water flow in the river is 130 m$^3$/s.

Water flow distribution was analyzed from 1982 to 1990. The minimum discharge was in 1984 (90.55 m$^3$/s), and the maximum was in 1985 (186.5 m$^3$/s). There is a correlation between the flow rate and the amount of precipitation, the least amount of precipitation reflected in the low level of flow [19-24]. From 1991 to 2000, the minimum water flow in the river was in 1992 (107.32 m$^3$/s), and the maximum was in 1994 (187.22 m$^3$/s). From 2001 to 2010, the minimum water flow in the river was in 2009 (85.33 m$^3$/s), and the maximum was in 2006 (211.18 m$^3$/s). The year 2006 was one, when the highest flow rate of the river was recorded. Since 2007 (117.6 m$^3$/s), there has been a gradual decrease in annual consumption values, which coincides with one of the hottest and driest years. The correlation of air temperature and average annual water consumption (-0.52), precipitation, and average annual water consumption (0.13) was carried out. Years with above-average consumption were 1982, 1985, 1986, 1988, 1993-1999, 2003 – 2006, 2010, and 2018. The minimum runoff for the observation period was in 2020 and amounted to 33.9 m$^3$/s, which is almost 12 times less than the average annual values. In hydrological terms, the period since 2007 has become quite difficult, the flow rate is below average, and rivers are shallowing. For the period from 2008 to 2020, 6 years with high water and 7 low water were recorded. At the same time, the period 2012 - 2016 was low-water. The minimum values are fixed in 2020.

![Fig 2. Average annual discharge of the River Seversky Donets (1982-2020).](image-url)
The period since 2007 has been characterized by reduced values of the average annual water consumption in the river, which is associated with a decrease for precipitation. The lack of water in some years does not pose a danger, but a prolonged lack of water is recorded for the region.

The Seversky Donets River is experiencing high anthropogenic pressure in an arid climate. Significant seasonal changes are characteristic of the water flow in the Seversky Donets River. The maximum impact on changes in water levels in the river is provided by snow nutrition, which is associated with uneven water consumption throughout the year. It should be noted that the observations at this post are of a non-permanent nature, therefore they do not allow using data for calculating water resources and predicting their changes without expanding the study area. However, the trends and directions of changes that are characteristic of this item are consistent with the changes taking place in arid areas.

Intensive use of river waters in industry and agriculture affects the ecological situation and increases pollution. Every year, 2 km$^3$ of river water is consumed for economic purposes, most of which is returned in the form of sewage and dirty discharges. The main pollutants are petroleum products, fertilizers, zinc and copper. To address issues related to improving the ecology and water quality, a program was adopted for the period from 2010 to 2020.

The water of the Seversky Donets River in the Rostov region has been characterized as consistently "dirty" for several years, but in 2011 the water condition improved slightly and the quality class moved to "very polluted", in 2020 the water quality became "polluted". Significant harm to the river is caused by the discharge of insufficiently treated and untreated wastewater from various enterprises. It is necessary to reduce the volume of discharge of insufficiently treated and untreated water in order to normalize the hydrological regime and improve the ecological situation of the river. It is also necessary to carry out systematic cleaning of sections of the riverbed with a high level of siltation, and also, taking into account existing and expected hydrological characteristics, optimally use hydraulic structures. The main source of pollution of the lower reaches of the river is the mine waters of coal industry facilities. The rest of the river is negatively affected by
wastewater from housing and communal services and agriculture, as well as food, metallurgical and other industries. At the same time, significant harm to the river is caused by the discharge of insufficiently treated and untreated wastewater from various enterprises.

4 Conclusion

The result of global warming in the XX century was an increase in air temperature, a reduction in winter ice, and an increase in the temperature of the upper water layers in summer. Low-frequency fluctuations with a duration of 10 - 30 years are distinguished, which are mainly determined by the variability of the atmospheric circulation of the Northern hemisphere. The direct influence of North Atlantic fluctuations on the formation of the runoff value of the Donets River is not observed. However, they affect the air temperature in the studied area. It is noted that an increase in the average annual air temperature leads to a reduction in the duration of the snow cover, which leads to an increase in soil nutrition and a redistribution of river runoff. The redistribution of runoff cannot be assessed unambiguously. On the one hand, there is a reduction in the danger from catastrophic floods, on the other hand, uniform flooding leads to a reduction in the risk of river shallowing. Significant seasonal changes are characteristic of the water flow in the Seversky Donets River. The maximum impact on changes in water levels in the river is provided by snow nutrition, which is associated with uneven water consumption throughout the year. The decrease in runoff and its seasonal redistribution are a reflection of modern physical and geographical processes and anthropogenic influence on watersheds. The general tendency to decrease the water content of rivers is characteristic of the entire river basin. It is planned to expand the study to identify further dynamics of climatic parameters and changes in runoff.

References

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